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ABSTRACT

In this introductory pamphlet, computers are defined, and the main components of a computer system (input, storage or memory, control, arithmetic logic, and output), the language of the computer and use of computers in education are discussed. The latter section considers computer science, computer-assisted instruction, programed instruction, educational games, and use of computers in counseling. Examples of programs in each area are given. A glossary is provided. The style is nontechnical and the treatment is brief. (JK)

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LAYMAN'S GUIDE TO THE USE OF COMPUTERS

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This booklet was prepared by the staff of the Division of Instructional Systems of the School District of Philadelphia.

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Section 1.00

INTRODUCTION

Computers are having a profound effect on today's society. Our lives are being influenced and even dependent upon these electronic devices. We are being rapidly relieved of arduous mental tasks in the way that manual tasks were relieved by machinery many years ago.

Since computers can hold the key to efficient living, knowledge of their use is of great importance. The individual who lacks a grasp of the potentials and limitations of these devices can be severely handicapped. Regardless of one's role in our society, a minimum knowledge of computers and data processing is essential.

Computers are being used effectively in the educational environment. Educators are utilizing technology to make possible more efficient information systems. Due to an increasing abundance of data upon which decisions must be made, data processing equipment is playing an increasingly important role in the operation of today's schools. School districts are using computer technology for handling business operation primarily to increase the purchasing power of the education dollar. The educator has become aware of the increased reliability of the information obtained, the speed of handling the information, and the variety of reports that are now available and help in the decision-making process.

School administrators and teachers are becoming increasingly aware of another important role computer technology is playing in today's schools. Computers are making very significant contributions in curriculum, through the teaching of electronic data processing principles, and in instruction, through the use of automatic devices to aid the teaching-learning process.

The area of instruction must be considered as a part of the educational endeavor in general. The instructional aspect of the educational system is but a subsystem, albeit a large and important subsystem of the total educational system. The system can be defined as a structure or organization of an orderly whole clearly showing the relationship among the parts and the relation of each part of the whole.

The educational system itself can be envisioned - a part of a larger supersystem of which the educ ... .l system is at the first level. For example, if public education (K-12) is considered the supersystem then the instructional system is considered a subsystem or part of that system. A part of the instructional subsystem is the computerized aspects of education. It is expected however, that, in the future, the computer applications in education at all systems levels will become increasingly evident. It is the purpose of this GUIDE to acquaint the reader with the uses of computers in education. The emphasis of the GUIDE will be in applications of the computer in the instructional subsystem. But before proceeding further the reader should become familiar with the nature of computers.

PREFACE

The Association for Educational Data Systems (AEDS) is happy to present this Layman's Guide, thus continuing its policy of helping to educate the public in modern technology. AEDS is a non-profit educational corporation consisting of professional educators and technical specialists oriented towards educational applications. Its purpose is to provide a form for the exchange of ideas and information about the relationship of modern technology and its impact on education. It is an association for those interested in keeping better informed about current developments and directions in educational data systems.

The emphasis of this guide is on instructional applications, showing how computers are now being used and can continue to be used to help in the educational process. It is designed to provide teachers, administrators, school board members, and parents with an introduction to some basic principles in data processing and to present an overview of the use of computers in instruction.

Section 2.00

WHAT IS A COMPUTER

HISTORICAL PERSPECTIVE

Throughout recorded history, few inventions have had an impact on humanity which compares with that of the computer. At every turn, modern man is confronted by activities or products which have directly or indirectly been affected by computers. From the morning papers, type for which may have been set by a computerized typesetter, to the television set on which he watches the late show, space age man cannot avoid coming in contact with computer affected influences.

Early man had very little difficulty keeping track of items he needed to count. For most purposes, his fingers sufficed. As his horizons expanded and his worldly possessions increased, man invented various methods of counting. Pebbles, sticks, and knotted cords handled his counting problems very satisfactorily. Eventually, the development of a numbering system became a necessity. Several systems which were invented proved to be very cumbersome when rapid or involved calculations were required. For example, the notation in the Roman Numeral system hardly allowed rapid or accurate involved calculations. Arabic numerals, which appeared in the 12th Century, however, allowed man's fertile mind to develop innumerable mathematical processes.

In time, as technology advanced, various mechanical devices were invented to aid in arriving at mathematical solutions. This notion of a mechanical counting device was not a new one.

Discovery of an abacus, was made in the Tigris-Euphrates Valley in the Middle East and has been dated at about 3500 B.C. The Chinese were aware of and used an abacus about 3000 years ago. The slide rule, which some consider the first analog computer, was developed in the 17th Century.

The invention of the first mechanical device capable of simple arithmetic (addition and subtraction) is credited to Blaise Pascal, the noted French philosopher and mathematician. He built his first "adding machine" in 1642. The "pocket adders" in common use today are descended from Pascal's machine. Gottfried Leibnitz, in 1671, proposed a machine which would multiply by a means of rapid addition.

After a period of about 100 years, rudimentary calculators began to appear. Although calculators were a great improvement, they were in no way automatic. If the res ts of one calculation were to be used in further calculations, the operator would have to remember those facts or record them on paper and re-enter them when necessary. The first machine that was capable of performing all four basic arithmetic operations in a reliable manner was built by C. X. Thomas in 1820 and was called the "Arithometer."

It was a nineteenth century British mathematician, Charles Babbage, who developed a mechanical device which would not only perform mathematical calculations, but store results for future use. During the period between 1812 and 1822, Babbage built a working model of his "Difference Engine." Babbage's Difference Engine was a device for automatically calculating entr s for mathematical tables of functions. In 1833 his "Analytical Engine" was conceived. Babbage's design for the Analytical Engine had all the elements of the modern-day digital computer. His two major inventions, the Difference Engine and the Analytical Engine, never became truly operational due to the lack of sophistication and precision in the machining industry. Babbage's theories, however, and many of his ideas were incorporated into the development of the first electronic computers. A recent vindication of Charles Babbage took place when a working model of his calculating machine was built from his drawings.

Dr. Herman Hollerith, a statistician with the U. S. Census Bureau, conceived and developed an idea for a mechanical means of recording, compiling and tabulating digital information. He introduced an electromechanical sensing device for recording data contained on punched cards. Hollerith's machines were first used in the compilation of the 1890 census.

Mark I, the first modern electromechanical computer having a stored program capacity, was built at Harvard in 1844, by Professor Howard Aiken. This computer was also called the Automatic Sequence Controlled Calculator.

The Mark I was 51 feet long, eight feet high, and weighed nearly 5 tons. Many of the component parts were standard IBM tabulating machine parts. The Mark I employed many of Charles Babbage's ideas. It performed automatically by following a sequence of instructions punched on paper tape, but was very slow by today's standards.

The development of the first electronic computer took place, in late 1946, at the University of Pennsylvania. With funds supplied by the Department of the Army, Dr. John W. Manchly designed and built ENIAC (Electronic Numerical Integrator And Calculator). ENIAC's main function was to calculate firing tables for military artillery and was first considered a special purpose computer.

ENIAC was a giant collection of over 18,800 vacuum tubes, relay switches, and 500,000 hand-soldered connections. The machine weighed over 30 tons and occupied 1500 square feet of floor space. In spite of the size and complexity of the machine and the laboriousness of wiring plugboards for each new program, ENIAC was over 1,000 times faster than its predecessor Mark I. While the Mark I computer could perform 10 additions a second, ENIAC could calculate 5,000 a second.

The major drawback of ENIAC was the difficult and time-consuming task of re-wiring the plugboards before a different program could be used. This problem was eased somewhat when the machine was modified to accommodate a flexible programming method. The new "von Neumann" programming method allowed the computer program itself to be stored in the computer itself just as data was stored. This feature made ENIAC the first easily programmable computer.

A direct descendant of ENIAC was the first commercially available computer, UNIVAC I. UNIVAC I (*UNIV*ersal *A*utomatic *C*omputer) contained about 5,000 vacuum tubes and was considerably smaller than its forerunners. It was also considerably faster. It could calculate an addition in 2 microseconds and multiply in 10 microseconds.

The growth of the computer following that time has been fantastic. Each technological development leads to faster, smaller, more accurate machines. Computers followed the path of vacuum tubes to transistors to integrated circuits. The ubiquitous "thinking machine" has become an integral part of science, industry, and commerce. From its halting first steps the computer has grown to be probably the most universally used business and scientific device.

We are now ready to define a computer as a device capable of accepting information, applying prescribed processes to the information, and supplying the results of these processes. It usually consists of input and output devices, storage, arithmetic and logical units, and a control unit.

In any computer, information is inserted, processed or operated upon by some method and then reproduced as new information (See Figure 1).

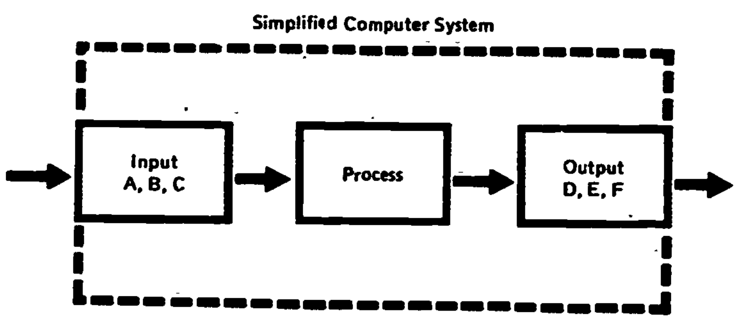

FIGURE 1.
Information Flow in a Computer System

Information can be thought of as knowledge to be processed by a computer organized for a specific purpose. For example, class, gender and attendance information is some data processed by a computer to make up report cards. The information is processed mathematically and logically. Comparing, sorting, and rearranging of information are the kinds of logical operations performed by the computer. The word "processing" refers to the operations performed using the information that is fed the computer (input).

As Figure 1 illustrates in a very simplified form, several "bits" (A, B, and C) of data are "input" into the computer. Some predetermined sequence of operations is performed on the data and the result is new information (D, E, and F). Each of the three blocks in Figure 1 can be considered steps in a linear sequence of operations. The steps are time-distributed which means that one step must be completed (or at least begun) before the next step is begun.

The electronic computer is made up of many basic circuits put together like building blocks, each containing resistors, capacitors, magnetic cores, diodes, and transistors. This equipment is frequently called "hardware" and may be considered to consist of five sections, each having a distinct function. However, the operation of each unit is dependent upon the other. In Figure 2, the arrows indicate the flow of operations.

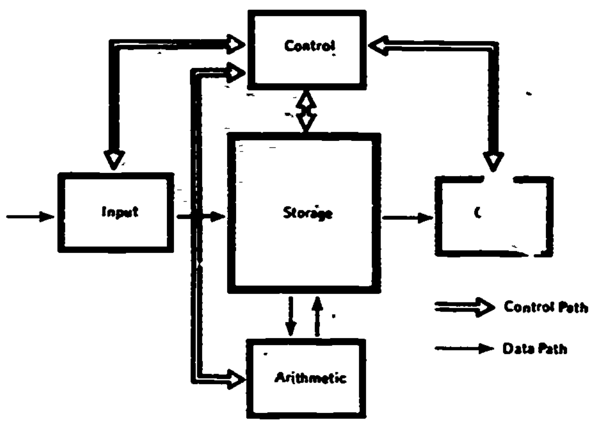

FIGURE 2.
Generalized Digital Computer

Figure 2 depicts an expanded and more generalized schematic representation of an electronic computer. The central processing unit (CPU) has been separated into three units – the control unit, the storage (memory) unit and the arithmetic unit. Two sets of arrows are included in the diagram; one depicting the path through which data flows; the other specifying the control path.

The arithmetic unit, control unit, and storage or memory unit are all contained in one cabinet (See Figure.3).

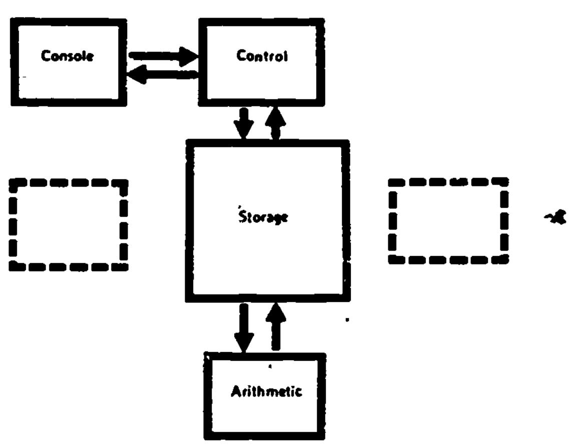

FIGURE 3.
Central Processor (CPU)

The console unit added to the CPU portion of the earlier figure provides a means of directly controlling the internal operation of the computer. The console may resemble a television with a typewriter attached to it. On the cathode-ray tube (CRT) information can be displayed describing what information is stored in memory. Also, the operations that are about to be performed can also be specified and displayed on the CRT. The computer operator can use the typewriter to type messages, to stop, start and otherwise assume control from the CPU.

A more complete schematic representation of a modern computer appears in Figure 4. The size of the main storage (memory) is much greater than the other units to emphasize the massive storage capabilities of computers today. The input (I/O) devices may be card, reader, magnetic tape unit, paper tape unit, or a teletype unit. The output devices may be a card punch, line printer, magnetic or paper tape or CRT units. Many input devices may be "tied" into a computer. These need devices called "data channels."

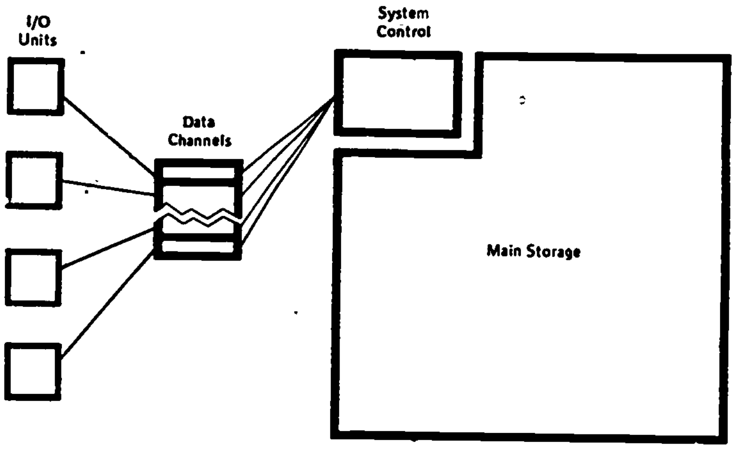

FIGURE 4.
Multi-access Digital Computer System

In sum, computers are considered to be divided into three parts: an input unit which feeds information into the machine; the main computer or central processor; and an output unit which produces the information (Figure 5).

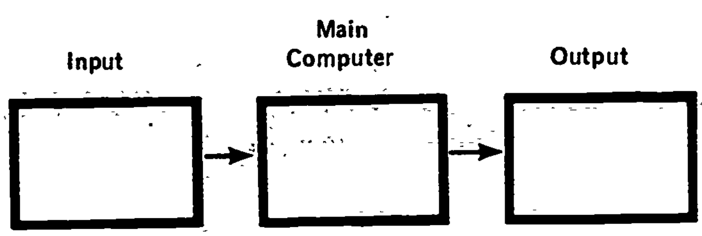

FIGURE 5.
Generalized Computer System

These sections work together to give the computer the ability to control its functions and to perform mathematical and logical operations. They are much more than just computational slaves because of their speed of calculation. They are information processors. They must be considered as machines which have infallible memories and, therefore, can be taught to play a reasonable game of chess or to keep a record of a student's learning pattern. They do this by remembering. They can "remember" every position they have seen before and also what move they then made. Computers are able to remember, but they cannot think, so they are entirely dependent on the people who run them.

Section 3.00

MAIN COMPONENTS OF A COMPUTER SYSTEM

INPUT

A computer cannot solve a problem or process any information unless it has the necessary facts or information. That part of the machinery which channels information into the computer is called the "input" section. The basic function of the input unit of the computer is to accept information and act upon it so that data can be used by the rest of the machine. This information must be in some regular coded form that can be sensed and converted into electrical impulses.

One widely used method of supplying input data is by means of punched cards. The position of the holes in the card determine the type of character that is presented. The card image in Figure 6 indicates the various alphameric (Alphabetic-numeric) and special characters that can be punched on a card.

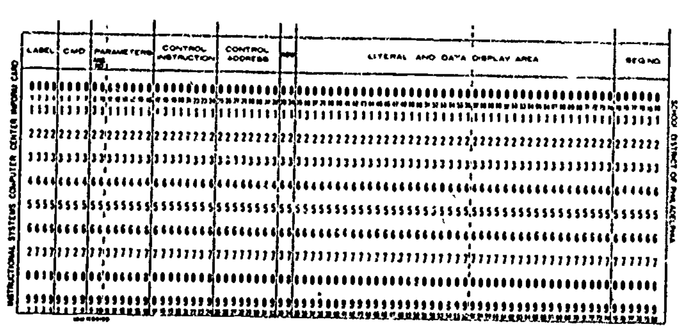

FIGURE 6.
A Card Image

A punch card is a standardized means of computer input. The card is of standard size and layout. In the card in Figure 6, there are 80 columns (left to right) and there are 12 fields (top to bottom). Thus, there are 960 distinct locations on a punch card. The keypunch machine is used to prepare the cards. The keypunch is comparable to a typewriter. An operator reads the source information and types it on a keyboard which causes the machine to punch the holes on the card.

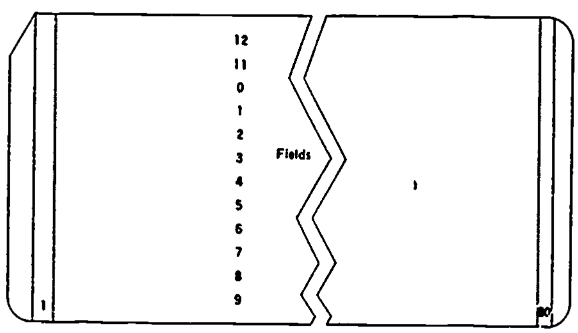

FIGURE 7.
Card Layout

Information from the punched cards is "read-in" and stored in the storage unit of the card reader itself. The information, represented as a hole in a card, is converted to an electrical impulse usable to the computer. Card reader units read approximately 200 cards per minute.

Information punched on cards may be converted by an independent device to magnetic-tape form which is then used as the input to the computer (Figure 8). Data storage on magnetic tape is much

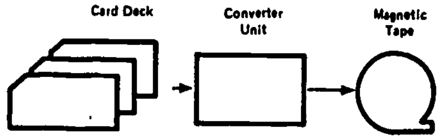

FIGURE 8.
Card-to-tape Converter

more efficient and economical. Magnetic tape storage is more efficient because input from tape is much faster, approximately 120,000 characters per second. On a standard magnetic tape 800 characters (about 10 punched cards) can be stored on an inch of tape. Magnetic tape units read approximately 150 inches of tape per second.

Another added advantage of storing data on magnetic tape is that it is highly compact, is durable, and is easily transportable. A 2400 foot reel of tape is only about 10 1/2 inches in diameter and weighs only a few pounds.

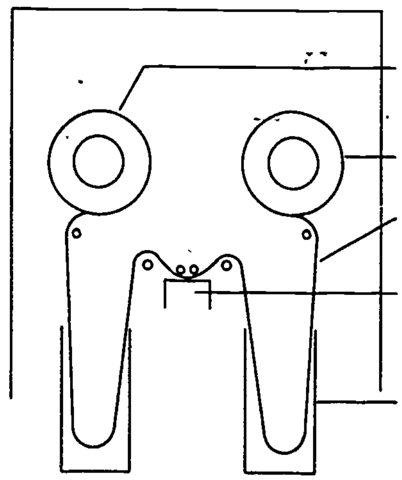

FIGURE 9.
Magnetic Tape Drive

Data is input from (or output to) magnetic tape by means of a Magnetic Tape Drive or Tape Transport Unit. The Tape Drive mechanism works in the same way as a home tape-recorder but with considerably greater speed. The magnetic tape is mounted on the left file hub, is threaded through the read-write head assembly and is wound around the machine hub on the right side of the tape drive. As the magnetic tape passes through the read-write assembly information can be written onto the tape or the read heads can detect the magnetized "spots" and read information stored on the tape.

STORAGE OR MEMORY

The storage or memory can be visualized as a large box divided into compartments, each containing information. This unit is like an indexed filing cabinet in which stored material is instantaneously accessible to the computer. The computer remembers, that is, it can store in its memory, information. Each location, position, or section of storage is numbered so that the stored data can be readily located. The amount of information that can be held within the computer at any one time is dependent on the size or capacity of the storage unit. By means of numerical addresses, a data processing system locates data and instruction.

Storage (memory) consists of many magnetic cores, tiny, doughnut-shaped objects composed of a ferric material that can be readily magnetized. A core is no larger than the head of a pin. Running through the center of each core are two and usually three wires — two wires control the magnetization and one determines whether the core is magnetized.

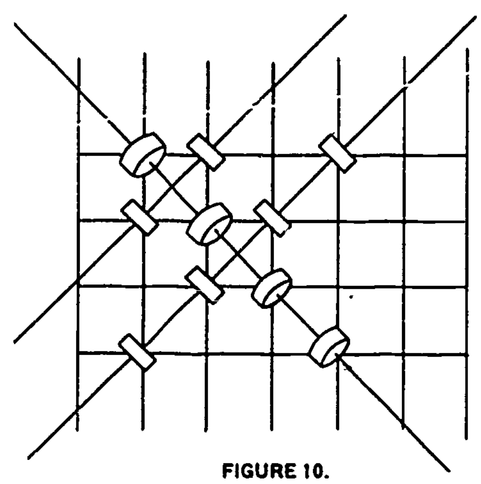

FIGURE 10.
Core Storage Plane

Two wires determine the location of the core or define the plane in which the core is located. If a core storage area can be envisioned as a slice of a cube divided horizontally and vertically then any smaller cube can be identified by knowing the column and the row within the plane. The address label for each core can then be specified for any location.

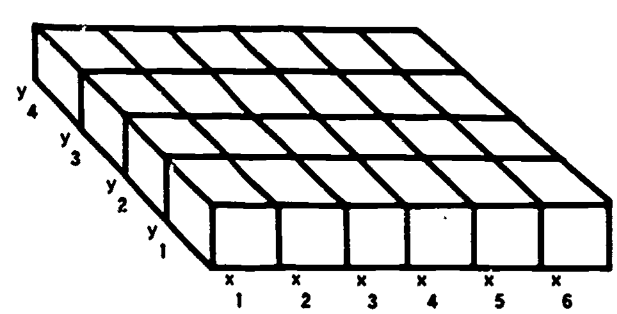

FIGURE 11.
Core Storage Plane

In order to magnetize any core electrical impulses must be sent through the two main wires that pass through the center of the core. One-half of the electrical impulse necessary to magnetize each core is sent through each wire.

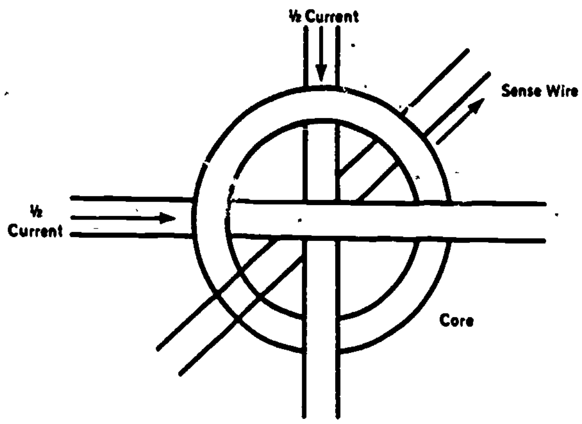

FIGURE 12.
A single Core Location

Data, as the name implies, is information needed to solve a problem, perform a calculation, or update student and teacher files. An instruction word is a computer word which tells the computer what to do. When both are in the main storage, instruction and problem data can be distinguished only when they are brought into the central processing unit (CPU). If information is brought into the CPU during the instruction cycle, it is interpreted as an instruction; if during the data cycle, it is considered as data. If information is placed in storage so that data are available during an instruction cycle, the computer treats the data like an instruction. This allows the computer to change its own instructions if these instructions are placed in storage during the data cycle.

CONTROL

The control unit directs the operation of the other units. It directs the flow of information in and out of the computer, as well as manipulating information inside the computer. It coordinates and programs the functions of the various parts of the computer. It obeys our instructions exactly. It works like a clock and insures that selected events occur at just the right time in relation to other events. It takes care of carrying out the instructions given to the machine and of executing the sequence or program of instructions. The list of instructions is called a "program." The control register (a device for storing a piece of information) in the control unit contains the current instructions for the machine at each cycle or step. Instructions tell from which register information is to be taken, which register is to receive information, and which register contains the next instruction to be executed. The machine needs only the position of the first instruction; given the information, it automatically executes a series of instructions.

ARITHMETIC AND LOGIC

The function of the arithmetic unit is to perform all of the computer's arithmetical and logical operations. It is composed of registers, analogous to the gears and wheels of a desk calculator, where numbers are entered and results are shown. It can add, subtract, and multiply in a manner similar to a desk calculator, but at a much higher speed. In addition to doing arithmetic, the computer can perform operations or distinguish between positive, negative or zero values. It can compare two items at a time, eliminate one item, compare the remaining item to a third item, and repeat the process. Instructions allow the computer to compare two numbers, find out if one is larger than, smaller than or equal to the other. These latter instructions are rules of Boolean algebra. These decision or branch statements are represented in mathematical notation as:

$<$ less than
$>$ greater than
$=$ equal to
$\leq$ less than or equal to
$\geq$ greater than or equal to
$\neq$ not equal to

The various registers in the arithmetic unit not only enable arithmetic (logical) operations, but can store information as well. Instructions written by the programmer or those logical sequences permanently stored in the computer can be used to "tell the computer" what operation to perform and what to do with the results. As an example of an arithmetic operation in the language of computers, consider the addition of two numbers. The numbers to be added are located in separate addressed locations or register numbers. The operations could be written as below.

INSTRUCTION	CONTENTS OF NAMED REGISTER
AR 3,5	+ 47
AR 3,6	+ 52

These two instructions perform the following operations: AR 3,5 instructs the computer to take the contents of general register 5 and place them in register 3. The next instruction, AR 3,6 instructs the computer to take the contents of register 6 and add them to the contents of register 3. The result is that the number +47 is taken from register 5 and placed in register 3, then +52 from register 6 is added to +47 to yield +99 in register 3. This step-by-step series of operations done in microseconds demonstrates the basic operations accomplished within the arithmetic unit of a computer.

OUTPUT

The information is released at an output device where it can be seen. Man cannot use the computer's solution if it is in the form of electrical impulses within the computer. Punched cards, paper tape, magnetic tape, typewriters and high speed printers are the common output devices. A television-like display tube may also be connected to the computer so that information can be received in the form of graphs or drawings. The same signals that are normally directed to a high speed printer may be used to operate valves, motors and controllers in an automatic industrial process. Examples of such processes are: digitally controlled machine tools, automatically controlled gasoline refineries, steel and chemical plants, etc.

All modern digital computers consist of these five functional components. The differences between digital computers are the capacity of the memory, speed of the arithmetic unit, and the number, variety and speed of the input and output units.

Section 4.00

THE LANGUAGE OF THE COMPUTER

Computers are automatic but instructions for every operation to be performed must be provided. This list of instructions is called a "program." The person who prepares the programs is called a programmer. The power of digital computers lies in their ability to follow a predetermined and self-contained sequence of instructions. The machine will follow exactly the steps which the program has specified. It will not change the sequence at any time. It will do precisely what it is instructed to do – nothing more or less. The earliest computers required the programmer to write instructions directly in the language of the machine – in long lists of numbers. This language, time consuming, tedious, is called "machine code." To use the language of the machine, a programmer has to write down a long series of instructions which are peculiar to the machine used. It may take a programmer many, many, hours to write the step-by-step instructions for the computer.

To demonstrate how difficult "machine coding" really is, consider the following arithmetic problem and the computer programs written to carry out its solution. The problem is:

Given three numbers located at three specified locations, add them up and place the sum in a fourth location. A limitation is that if any of the three numbers is zero, do not sum the numbers and store zero in the fourth location.

To further define the problem the three numbers are X1, X2 and X3 and are located in the three storage locations addressed as 94, 95 and 96. The sum of X1, X2 and X3 should go at address 97 if no number is zero.

The machine language program for the solution to this problem is below with an explanation of what operation is performed.

ADDRESS in storage	INSTRUCTION	OPERATION PERFORMED
51	0194	LOAD contents of register 94 into a special register "A"
52	0459	IF "A" is zero, JUMP to location 59; if not continue
53	0195	LOAD contents of register 95 into "A"
54	0459	Same as 52
55	0196	LOAD contents of register 96 into "A"
56	0459	Same as 52
57	0394	Add X1 to contents of "A"
58	0395	Add X2 to contents of "A"
59	0299	STORE "A" in location 99
60	6666	STOP.

The machine language instructions in the center column bear little resemblance to what arithmetic and logical operations are being performed. The first two digits of the instruction specify a "wired-in" code which causes the computer to perform a specified operation. In this case 01 means LOAD, 02 means STORE, 03 means ADD and 04 means JUMP. The second two digits in the instruction define the address of the information to be used in the operation.

A slightly more sophisticated language is *assembly language*. The sophistication lies mainly in the mnemonic correspondence between the written instruction and the description of the actual operation. The program written in machine language to solve the addition problem is written now in assembly language.

ADDRESS in storage	MACHINE LANGUAGE	ASSEMBLY LANGUAGE		
51	0194		LDA	X1
52	0459		ZJP	STORE
53	0195		LDA	XZ
54	0459		ZJP	STORE
55	0196		LDA	X3
56	0459		ZJP	STORE
57	0394		ADD	X1
58	0395		ADD	X2
59	0299	STORE	STA	RESULT
60	6666		STOP	

To make it easier for people to use computers, languages have been devised which allow the computer to accept instructions in a language closer to the language of every day use, or more nearly resembling mathematics than machine code. These languages are called *"high-level languages."* Examples of these "high-level languages" are:

	ALGOL	(*ALGO*rithmic *L*anguage)
	FORTRAN	(*FOR*mula *TRAN*slation)
and	COBOL	(*CO*mmon *B*usiness-*O*riented *L*anguage).

The first two are primarily used for scientific problems, and the third for business applications. The programmer would write the instruction A+B and this instruction would then be translated to machine code before the program can be executed. This translation is generally performed by the computer under the control of a special program called a "compiler." The compiler is written in machine code and is stored in the computer. When the high level language program is read into the computer, the compiler translates it into machine code before the instructions can be executed.

Returning to the sample addition problem, the FORTRAN language can also be used to write the program to solve the problem. The *FORTRAN* program that appears below is specific to this problem but could readily be made general enough to solve any problem such as the one presented. The FORTRAN program does not specify the actual locations

```
      DIMENSION X (3)
      X(1) = X1
      X(2) = X2
      X(3) = X3
      DO 5 I = 1,3
      IF (X(I)) 5,10,5
    5 CONTINUE
      X4 = (X(1)+X(2)+X(3))
   10 STOP
```

of the numerical values of interest. The values can be stored at any location which would be labeled X1, X2 or X3. The numbers are also stored in locations X(1), X(2) and X(3). Suffice it to say that the *FORTRAN* language is a better approximation to the English language and to mathematical notation than the "lower level" languages. This alone makes the programming task easier.

All of the foregoing description of languages at any level of sophistication fall under the general category of "software." Although certain instructions are "wired-in", meaning that a physical circuit has been made, these instructions are also considered part of the "software."

The actual processors, the CPU, the card readers and the tape drives are the "hardware" of a computer system. The physical equipment of a computer, from the ferric cores to the finished cabinets, is the hardware.

Section 5.00

USES OF COMPUTERS IN EDUCATION

COMPUTERS AS AN ADMINISTRATIVE AID

Administrative data processing is now part of a school's operation dealing with student, material, and other resources necessary for the proper functioning of the school's activities. Information is now able to be wired effectively to provide for better determining teacher loads and requirements, making budget requests, apportioning school funds and costs, and for proper decision making. Decisions involving business office applications which include budgeting, purchasing, payroll supply requisitions and inventory have relieved administrators from non-professional clerical routines.

Tasks such as scheduling, attendance accounting, testing, and reporting procedures are essentially counting and recording tasks. The most efficient means of handling these tasks is through computer-assisted methods. For scheduling and taking account of attendance and other such clerical duties objections about the intrusion of computers seldom arise. In the domain of testing, grading and evaluation, some philosophical objections are still raised. The hesitancy about the depersonalization of the individual through computerization of records is still with us. But since computers work with numbers, measurable attributes and do not work with opinion and impressions as data, evaluation does require personal attention. Techniques are not available to quantify all human attributes that are gauged in assessing a student's performance in school. Decisions regarding an individual's future cannot be relegated to a straightforward mathematical procedure.

Computers do, however, facilitate the storage, retrieval, and summarization of the quantifiable attributes of students. The increased efficiency of information processing is what makes computer applications in administrative tasks essential.

The use of computerized scheduling for assigning pupils to classes has become a fairly widespread practice. Anyone who has been involved in the rostering of students can attest to the tediousness of the task. Building a master schedule and registering and scheduling students are extremely complex and time-consuming. Use of the computer provides more detailed information for planning curricular offerings. With increased numbers of students computerized scheduling is becoming a common practice.

COMPUTERS AS AIDS TO EDUCATIONAL RESEARCH

A number of educational or educationally-oriented institutions in the United States have created centralized "data banks." Advantage is being made of the speed and capacity of the computer to storing and retrieving information about instructional materials, teaching strategies, literature in education and actual student test and biographical information. Information can be stored in a "data bank" or "data center" to serve the ..eeds of the administrator, teacher, counselor, student, and education planner. The detailed information that can be stored and retrieved rapidly and accurately will provide invaluable information for decision-making in all areas of the educational domain.

Project TALENT, for example, is a major effort to establish a comprehensive data bank in the field of education. The data files at Project TALENT contain extensive student aptitude, interest, attitude and biographic information on over 400,000 secondary-school students. Project TALENT includes the provision to collect follow-up, longitudinal information for a period of 20 years.

The objectives of Project TALENT include the development of an inventory of characteristics of high-school students. Another objective of TALENT is to develop, validate, and provide norms for a set of tests by which other instruments could be compared.

TIME SHARING

Time-sharing is a means whereby a number of users can have access to a computer at the same time the system reacts to the user as if the entire capability of the computer were available exclusively to that user, although a large number of other users may also be accessing the computer at the same time. A time-sharing system is usually interactive and the computer may be communicated within what is known as a "conversational mode." In time-sharing, each user may access the entire

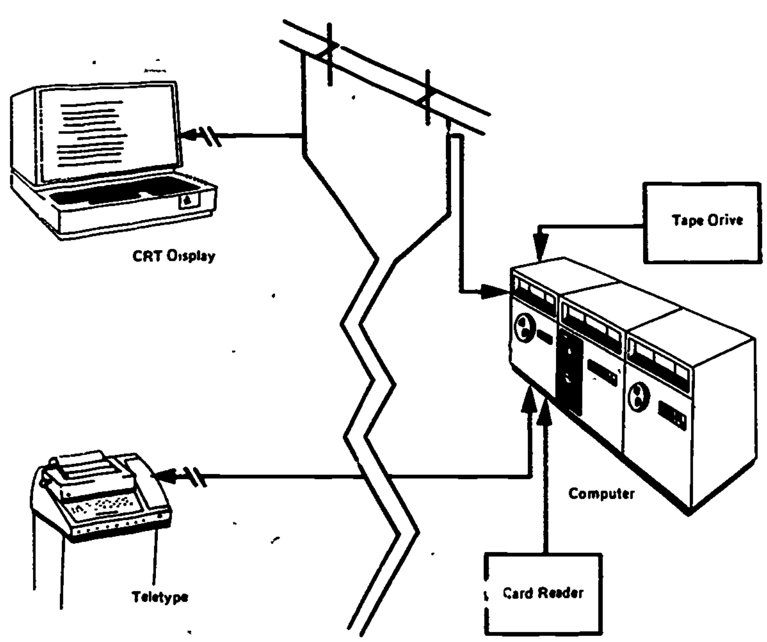

FIGURE 13.
Remote Communications System (Time-shared)

programming system, being able to use programs available in the system. Each user is able to store, retrieve, and update files of programs and data. Usually stored information can be produced for access by other users. Often users can communicate with each other through the system.

Time-sharing is popular with schools because of ease of usage and economy in having many students share in the use of a computer. Time-sharing languages, like BASIC, are relatively easy to learn, and computer time and terminals can be rented on a monthly basis. Time-sharing services may be expanded with the addition of more terminals.

As can be seen from Figure 13, a time-sharing computer system can operate using remote terminals as well as the usual peripheral I/O devices common to computer installations. Actual access time is so fast that all I/O devices appear to operate simultaneously.

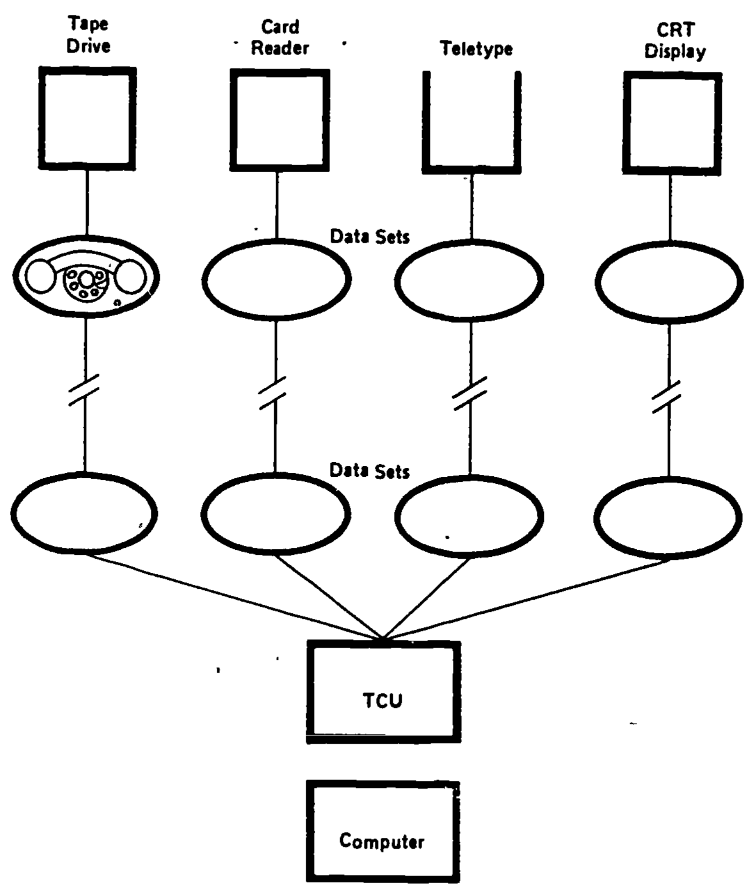

FIGURE 14.
The TCU permits communication with a variety of time-shared I/O devices

An essential feature of the remote access time-sharing system is the Transmission Control Unit (TCU) which permits a computer to function as a data transmission and receiving device. When transmitting data the TCU converts electronic impulses from the computer into electronic signals for transmission by a data set. A data set is similar to a telephone and the signals are similar to those on a "touch-tone" telephone. The tones or signals can be transmitted over regular telephone lines. At the receiving end of the network a similar data set converts the transmitted impulses back to electrical signals suitable to the receiving device; e.g., teletypewriter or cathode-ray tube display. (See Figure 14.)

Since computers operate at high speeds it would be inefficient to tie up the computer with the transmission of data at relatively slow speeds. To counteract this, some TCU's are equipped with buffers which are memory units that receive data from a computer at a high speed, store the data, convert it to the proper code, and slow the data down to the transmission speed required by the receiving equipment or communication service. This operation is reversed when data transmission flows from a low-speed device to the computer.

The computer terminals referred to above are remote terminals situated at the user's location. A widely used time-sharing terminal, especially for school use, is the teletypewriter terminal. A common model is the ASR 33, manufactured by the Teletype Corporation. The teletypewriter is relatively easy to install and requires no special facilities other than standard electrical outlets and a telephone line. More expensive terminals have desirable features in that they are less noisy and print answers at a faster rate.

The teletypewriter terminal for a school will generally consist of a typewriter keyboard on a stand, a telephone data set, and a paper tape read-punch mechanism. The paper tape punch permits programs to be prepared even when the terminal is not connected to the computer. After the program has been punched on the paper tape, the paper tape reader can be connected to the computer and the program entered via the paper tape reader. Also the program may be entered directly via the teletype. A terminal with the paper tape read-punch unit is called an ASR terminal (automatic send-receive). A terminal without the paper tape punch reader is called a KSR (keyboard send-receive) terminal. Teletype models range upward to the 35 and 37, etc., each higher model number being more expensive than the lower number with greater durability, speed and quiet operation commanding the higher prices.

For mobility a teletype can be purchased mounted on wheels and equipped with a data set and plug-in jack. This mobile terminal can be moved from one classroom to another wherever both telephone outlets and power outlets are available. The installation of telephone jacks is a relatively inexpensive cost for the mobile teletype.

Many different commercial manufacturers have portable teletypes available. These portable terminals may not have a data set, but may, instead, work with a voice telephone made adaptable to the terminal and thereby to the computer via an accoustic coupler which, when the receiver is placed upon it, converts the terminal impulses to a signal for transmission via the voice lines.

Several factors may affect the performance of a time-sharing system. Most evident is the speed of the system itself, some computer equipment being faster than others; the more users on the system, the slower the response. When a large number of users are involved, a significant difference in the response time may occur. The type of users also affects the response time. For example, if all of the users have needs requiring large files of information, if users store many programs, if all of the users are making extensive use of the CPU, or if they are using the system at approximately the same time, a decrease in service as far as fast response time to the user is concerned, may occur. This reduced service capacity usually does not appreciably affect the effectiveness of the service and frequently can be measured in seconds.

COMPUTERS AS SUBJECT OF INSTRUCTION

Twenty years ago, computer science as a discipline did not exist. Separate courses were offered in some large universities, but primarily to graduate students. Computer science can be defined as "the science of representing and processing information with the logical engines called computers." The pure computer scientist is concerned with the machine itself and the more theoretical aspects of computers, whereas the applied computer scientist is more concerned with the practical problems of efficiently getting information in and out of the computer. As computers are becoming more and more an integral part of our environment, schools and colleges are building the knowledge of computers and their applications into curricula and courses at all levels.

Computer science and programming courses are being given increasingly at the secondary school level. These courses are generally of a survey nature providing the student with a broad overview of computer science. The amount of use of computers is dependent upon the availability of a computer installation.

Programs at the Bachelor's level, through the doctoral level, are becoming increasingly evident. A Bachelor's level program generally includes courses in computer science and programming. Since many educators agree that too much specialization at the undergraduate level is not highly desirable the computer courses supplement a broad educational background. At the Master's level courses are more advanced and concentrated than at the Bachelor's level.

Existing programs at the Doctoral level are quite varied and are largely a function of the interests and capabilities of the faculty. The objectives of these programs are to produce students who are capable of conducting research, of teaching computer science, and who will make original contributions in the field of computer science.

Computer programming has shown to be of interest to all students. For the slower student it offers a new topic free of the many frustrations and hostilities associated with topics which depend on concepts which have not been mastered. For the gifted, it provides a tool for probing challenging problems, free of the monotonous computation that is allocated to the computer.

As a subject of instruction in the classroom, the computer has many uses. It can be employed as a drill master to reinforce concepts developed as part of a discipline being taught in the classroom, or it can be used to provide exercises in algorithmic processes. It performs tedious and lengthy calculations in order to expedite a student's comprehension of a mathematics or science application. It can be used by students to simulate physical, mathematical and other situations which can be developed for analysis. The computer can be utilized in any discipline (exemplified by students who write programs to translate Spanish into English, play games, or analyze musical compositions).

Computer education begins with an appreciation of the immense power and capabilities of the computer, and also an awareness of its limitations and its complete dependence upon human intelligence. As more and more computers are being installed, major countries of the world are becoming dependent on them in many aspects of national life. Whereas, the computer was used initially in solving problems of a numerical nature in science and engineering, this usage is now overshadowed by applications in commerce, business and industry. Computers are information processors. Students must not grow up in ignorance of this new social and industrial revolution. Students may eventually find satisfying careers in developing computers or in working with them in some field of application. Others, less directly involved, will need to be sufficiently well-informed to be able to make use of computers whenever appropriate.

It has been found, based on several years of experience with students learning computer concepts, that *students respond with keenness and interest to computer exposure.* It seems appropriate that students begin a broad-based program of understanding and appreciating the capabilities of the computer early in their school life. This education should not be specific in terms of developing expertise in programming, but instead, should be geared to provide a general foundation for subsequent education in more specialized aspects of computer work for those pupils wishing to pursue this area, and a broad-based introduction for those who will not take further specialized courses in computers.

The computer has a very important application in the classroom in the teaching of algorithmic analysis, the step-by-step procedure necessary to solve a problem. Techniques such as "flowcharting" and the need for the clear definition of a problem for solution using the computer, have served to make mathematics more of a dynamic and individual experience for the student. The computer has also made a significant contribution to the science curriculum in the solution of scientific problems, eliminating the tedious calculations that may be required for physics and chemistry problems thus opening up new areas for investigation.

Using the capabilities of the computer contributes to the understanding of various disciplines, broadening a student's view of possible applications. Becoming aware of the capabilities and limitations of computers, a student will explore many areas to determine those characteristics which make a problem suitable for computer solution.

The computer can be a definite boon to both the deductive and inductive learning process. In the area of dynamic drill the computer can be used to give repeated examples that demonstrate, for example, that a major theorem in geometry is valid. The theorem is introduced, the blackboard examples are given, then the further problems can be checked out with the computer, thus developing deductive reasoning.

In like fashion, inductive solutions are possible. In mathematics classes, for example, the applications and uses of the computer are many. Complex calculations can be carried out and results can be displayed almost instantaneously. Once the computer program for a certain type of problem has been developed, both the teacher and the students can concentrate on the mathematical structure and the physical significance of the results obtained. From such a technique of problem analysis and exploration, the student can develop a feeling for what is likely to happen and for the intrinsic mathematical and physical properties of the system represented by the problem. Students can participate directly in the investigation of the mathematics concepts and can learn by inference.

Recognizing the applications of computers to classroom instructions various manufacturers have contributed to a proliferation of computer equipment. Companies like Control Data Corporation, Digital Equipment Corporation, General Electric, Hewlett Packard, IBM, and Scientific Data Systems provide various types of "hardware" that can be used in the instructional program.

Communication with the computer may be through a problem solving language characterized by active on-line interaction between the user and the computer. Most problem solving languages evaluate each typed statement after it has been completed. These languages are suitable for both individual problem solving and curriculum demonstration applications. Problems can be coded quickly and the results displayed within minutes.

BASIC, originally developed at Dartmouth College for a GE Computer, is a typical programming language. It has been modified for use on many other computers; such as those produced by Scientific Data Systems, Hewlett Packard, IBM, and Digital Equipment Corporation. A major advantage of BASIC is its simplicity and ease of learning.

JOSS is another problem solving language. Originally used by the RAND Corporation, JOSS has been adapted to the IBM 360 System. It is more difficult to learn than BASIC but allows more flexibility of programming. JOSS has not been used very much in high school programs. TELCOMP is a JOSS-like language developed by Bolt, Beranek, and Newman for a time-sharing application. TELCOMP has been used on the Digital Equipment system. CAL is another problem solving language similar to JOSS, developed at the University of California for the SDS/940 Computer. FORTRAN (*For*mula *Tran*slation), a popular problem solving language developed by IBM and its customers is widely used in scientific applications and in some business applications. FORTRAN is more complex than BASIC, but allows a wider range of applications. Many versions of FORTRAN are in existence, the newer the version, the higher the number, e.g., Fortran V is a later version than Fortran III. ALGOL (*Algo*rithmic *L*anguage) is a universal programming language with scientific applications. ALGOL has met with wide acceptance abroad. Also used are COBOL (*Co*mmon *B*usiness *O*riented *L*anguage), APL (*A P*rogramming *L*anguage) and PL/1 (*P*rogramming *L*anguage/1). A thorough understanding of at least one of these languages is essential if a student wishes to become a professional computer programmer.

COBOL is a popular computer language for business programming, being operable on most computers. It is especially useful for starting and updating large data records and for charting reports. It is a verbal language and can be written in narrative form. COBOL is the language used to prepare inventories, salaries, and records.

APL is a problem solving language that operates on a variety of IBM computers including the IBM 1130, 1500 and 360 systems. The teletypewriter terminal is the usual communication device used with these systems. APL notation uses special keyboard characters to represent complex mathematical operations with few symbols and is very powerful in its capabilities. One disadvantage of APL, however, is its difference from standard mathematical notation found in textbooks.

USES OF COMPUTERS IN EDUCATION

An obvious use of the computer in education is in preparing people for employment in a cluster of data processing job opportunities. Recent requirements of industry and science have created a tremendous demand for people skilled in the technical field of data processing. Many new industries in engineering, electronics, missiles and manufacturing are requiring data processing technicians who can work side by side with the engineer or scientist to help analyze the specific problem at hand and devise a way to instruct the computer to achieve the desired results.

Good careers in data processing are available to those who know how to program, operate and control data processing equipment. There is need for people scientifically trained and familiar with the basic concepts of systems and the stored programming concepts of electronic computers. Young men and women who wish to prepare for technical careers in this area are looking to vocational education for their educational opportunities. The vocational education field, within its present framework, can administer the type of program that can help fill the demand for trained personnel on the technician level. There are many existing curricula on a post-high school level and in junior colleges that have helped individuals acquire a marketable skill by providing them with the preparation they need to cope with the sweeping economic and social changes in today's society. Recent surveys indicate that people are needed to fill jobs in data processing. The American Association of College Schools of Business's publication in October, 1969 compiled the following statistics:

	Needed by 1975	Graduates Avail.	Est. Deficit
Systems Analyst	165,000	23,000	142,000
Programmers	154,000	66,000	88,000
Operators	106,000	65,000	41,000

Based on this evidence, it seems clear that educators, especially in the area of vocational training, are providing a greatly needed service, by making training in data processing available. Business data processing courses at the secondary level are being offered in schools across the country. Two-year post-high school courses in junior colleges and technical institutes are training students as programmers for working in business and industrial settings using the computer to solve technical problems. At the conclusion of such courses the graduate is securing employment in either a business organization or in a technical firm, sometimes requiring additional training in that organization's procedures and the particular equipment used. Post-high school training is filling the demand for trained personnel on the technician level.

THE COMPUTER AS AN INSTRUCTIONAL AID

Educators recognize the importance of the "systems approach" in education to help organize the learning environment in the schools and aid in the individualization of instruction. Every aspect of the educational system is considered part of a total system geared to individualizing learning, and thus producing educational results superior to those produced before.

The "systems approach" in education involves the following:

1. Combination of components that contribute to specific objectives which involves the improvement of the learner.

2. Production of information for "feedback" to other components of the system for appropriate action so that the system is self-correcting.

3. Inclusion of "feedback" as a continuous interaction between components, eventually leading to a better product.

Since technology has become available to assist teachers and students in the learning process, individualized instruction through educational technology provides a means of dealing with differences between students thereby helping each pupil perform to the best of his ability.

COMPUTER ASSISTED INSTRUCTION

Computer Assisted Instruction (CAI) can be considered a system in which a central computer acts as an intermediary between the student and a body of knowledge carrying out instructional strategies as programmed by the educator. A form of conversational interaction between student and system usually transpires and the computer presents information which has been stored in the computer.

The computer can handle many pupils simultaneously on an individual basis, meeting the instructional need of each pupil. A number of students may interact with the system simultaneously on a time-sharing basis, each student working at his own pace on the same or on different courses. The computer provides the student with his own individualized lesson, beginning the instruction exactly where he left off the day before. As he proceeds through his lesson the computer keeps a record of his answers. If the student receives a score of 80% or higher, for example, the computer may automatically place him in an instructional level of greater difficulty. If the student is scoring below 60%, the computer may shift him to a less difficult instructional level. In this way the necessity for placing him in a particular instructional "track" for the whole year is eliminated. The computer offers a great deal of flexibility which the conventional teaching-learning situation is not able to offer.

The computer with its extensive monitoring equipment enables researchers to collect data relevant to the learning process of students and thus contribute to the fund of knowledge on educational psychology. The main features of CAI are individualized instruction, self-pacing, immediate feedback and automatic record-keeping.

A teletypewriter connected to a computer can provide drill materials to students in subject areas such as arithmetic and spelling. The materials can be carefully and logically sequenced and can be presented to the student on the basis of his past performance in a manner that insures continuous "feedback." Appropriate remediation and enrichment material can provide for a variety of individual differences. Material in virtually any subject area can be presented to the student using a variety of presentation modes and a variety of response modes (e.g., printed, visual, audio, graphic).

CAI is based upon some of the same theoretical foundations as programmed instruction. In fact, many persons, now active in the field cite their own personal experiences with programmed instruction (PI) as the basis for their current interest in CAI. In its early stages of development, PI included the following essential characteristics:

1. Precise statements of instructional objectives in behavioral terms.
2. Presenting material in a carefully and logically sequenced order leading to criterion performance.
3. Providing for continuous and active student involvement – overt, if possible.

4. Providing continuous feedback on student performance.

5. Providing continuous reinforcement — usually in the form of success.

6. Permitting the student to proceed at his chosen rate of speed.

In general, PI aims to provide the student with a prescription for behavior of some type and to guide the student to conform to the pattern prescribed.

PROGRAMMED INSTRUCTION TO COMPUTER ASSISTED INSTRUCTION

As early as 1960, some writers began to look to the computer as an aid in overcoming the inherent shortcomings of the simple teaching machine or the programmed textbook. Computer-based programmed instruction added these capabilities:

1. Sequencing of frames as a function of student performance. For example, on the basis of his response on a specific criterion frame, and/or his history of performance on related criterion frames, a student can be, a) given additional remedial or practice material, b) continued in the linear sequence, c) branched ahead to more challenging material.
2. The student is given truly "immediate" response confirmation or correction. The most sophisticated CAI systems provide feedback in less than a second and some strive for a millisecond time lapse. This has significant implications from a theoretical as well as a practical point of view.
3. The most highly developed CAI systems utilize a wide variety of presentation modes, including audio, slides, motion pictures and graphics.
4. These systems also provide for a variety of student response modes ranging from simple selection ("Strike the 'A' key") to typing and light pen selection or sketching (pen sensitized to light on a screen). Voice-recognition techniques which will enable the computer to respond to spoken commands of the student will very likely be available within the next few years.

There are three approaches to CAI which represent different levels of interaction between student and the instructional system. Only two of the three approaches are fully operational at present: (1) Drill and practice. This is the simplest instructional system. Instruction provided by this approach is usually supplementary to the traditional instruction provided by the classroom teacher. The new topic or concept is introduced by the teacher, but students work at the terminals on exercises or reading material previously introduced in the class. (2) The tutorial system. The tutorial system is intended to provide as much of the actual instruction as possible. The tutorial assumes the major burden of instruction rather than a supplementary role, like the drill and practice system. (3) The dialogue system. This mode provides for a free exchange of questions and answers between student and machine.

Computer Assisted Instruction can be described as multiple-access, interactive, on-line, and timed-shared. With multiple-access capability means, the computer system is available to many students. The Plato Project at the University of Illinois has a capacity of 5,000 student terminals. In New York City, approximately 200 student terminals in a number of different schools are operated from a single computer.

Interactive CAI is coming to mean two things. First, you can interact with material by exploring what's on the data base, much as you can explore the index of a library, and then search the context of the books to which it leads you. Or, you can be led through the material in an orderly way as a teacher would do, the computer system dispensing information, asking questions, explaining and repeating, depending on the student's answers to questions about the lesson being given. While on-line, the student terminal is directly connected to the computer so that the interaction is conversational. It appears to the student that he has the full attention of the computer teacher. The computer response is rapid though the computer can share its time among many terminals.

In its simplest form the computer process of leading a student through the curriculum material seems no different than that used in programmed textbooks or teaching machines. The material is reduced to small, bits of information, called frames. Step-by-step these frames are presented to the student, appearing before him as a typewriter-like output of the computer or as an image on the screen of a display device. At each step he is asked a question about the curriculum material in the frame to test his understanding. The computer examines his answer and then directs him to the next frame or back to a previous frame or to a more explanatory series of remedial frames. The system may use the past performance of the student as a basis for presenting the next item of learning. A really sophisticated tutorial program provides a private instructor to an individual.

The logical decision capabilities of the computer enables the system to examine a student's history of answers and present material based on past experiences with student's having similar backgrounds. The goal of individualized instruction will allow not only for the differences of the rate of learning but also for differences in skill level. CAI programs offer the opportunity to multiply the effect of the best teachers by repetitive use of programs generated by their experience.

One of the most useful features of CAI is the availability of performance records. The computer can maintain detailed records of each session spent at a terminal. The progress of each student and data from performance records can be used to compile statistics and generate reports of the student's performance. Complete records of the learner's progress are compiled by the computer and available to the teacher. The teacher has complete records on the progress of each student.

The inherent limitations in classroom teaching which patterns instruction to some hypothetical average student rather than to needs of individual students has been recognized for years. Conventional classroom methods critically limit or make nearly impossible efforts to individualize instruction. A high turnover rate among teachers aggravates the problem.

Although teachers have been trying for many years to individualize work for each child in the classroom, even the most successful could not approach what the computer is able to do. The student can receive an individualized lesson and can actively engage in the learning process. Once the learner's needs have been determined, the computer channel the appropriate instructional levels of materials to the student based on the learner's rate and learning style.

A classroom teacher cannot humanly do in one day all that the computer does in the way of diagnosis, drill, and grading each child on a daily, individual basis.

Therefore the advantages of CAI can be stated as follows:

1. The machine never gets tired.
2. The instruction is private, with the individual proceeding at his own rate. The slow student is not embarrassed or pushed ahead without comprehending what's going on. The accelerated and advanced student does not get bored by a pace directed to the "average" student.
3. The student is given an opportunity to advance to new work or repeat material aided by a training system which monitors his performance.
4. Curriculum is developed and tested.
5. A complete, instantly available record is provided on each student's achievement.

The use of the computer in instruction is beginning to influence and change the role of the teacher. Since the computer cannot reinforce curiosity, inspire creativity or develop interpersonal attitudes, only a human being can teach perception and understanding. The teacher, relieved by the computer of chores that a machine can do better, is freed for those responsibilities which only human beings can do.

The major disadvantage of CAI at the present time is cost. If on-line computer-assisted instruction is to become a normal, integral part of the instructional system, the cost per student must be greatly reduced. Improved time-sharing capabilities, reduced hardware costs and increased storage and process capacities are being explored, however, now that some impressive statistics have appeared showing the effectiveness of CAI (e.g., New York and Philadelphia School Systems. McComb, Mississippi and Waterford, Michigan School Systems).

COMPUTER MANAGED INSTRUCTION

In computer managed instruction (CMI), the primary function of the computer is to assist the teacher and student in planning instructional sequences for material, either on the computer itself or the actual instruction may be a self-instructional package (programmed instruction), conventional tests, or other media. The computer offers a "prescription" to the student. The student does not constantly come in contact directly with the computer. The computer does not teach the student. The computer becomes an information system which records the student's responses and monitors his progress.

The role of the computer is that of monitoring and operating an information system which is used to supplement traditional instruction.

The computer may introduce the student to a concept or other item of information and then test him on it. If the student has understood the material, he may be told to study more difficult concepts. If the lesson gives him difficulty, he may be assigned material designed to give him clarification and individual tutoring in the particular problem area.

A student enrolled in a computer-managed instruction system may be administered diagnostic tests to determine overall achievement status and particular learning characteristics. Information resulting from the prescribed tests will be stored in the student data file. These records might include information about a student's intellectual interests, background, task performance, goals, meaningful experiences, failures, and personality conflicts. These records would be used by a CMI system to make the teaching decisions concerning each individual student.

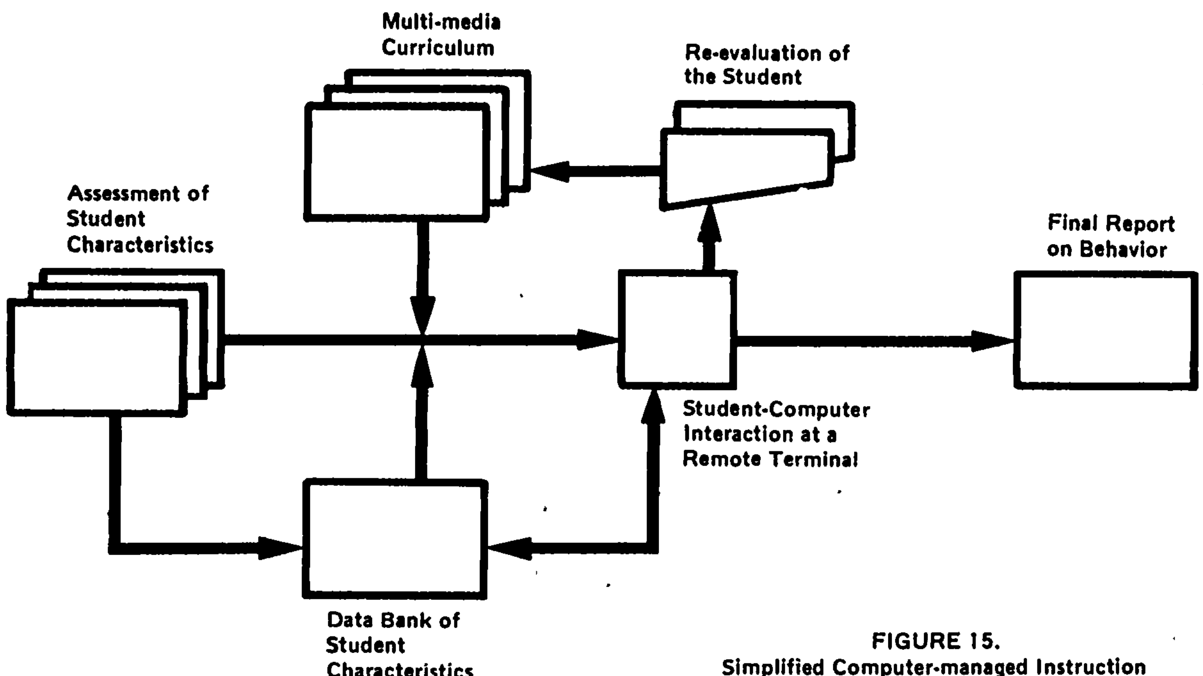

FIGURE 15.
Simplified Computer-managed Instruction (CMI) System

Computer managed instruction relies upon a variety of multi-media materials. CMI as a system of instruction, offers an individualized, multi-media approach to instruction. The student is directed by the computer to a variety of media which best suit his optimum learning characteristics. It uses the capability of a computer to manage the progress of a student through a sequence of instruction, testing that progress at many points. Students benefit from the immediate feedback capabilities of the computer even though there may be no direct instruction via the computer. The system can be assumed to involve testing, diagnosis, remediation, and recording of information under the direction of a teacher. The remediation can be in the form of media and texts available to the student for individualized study.

There is a close relationship between CAI and CMI; both can use the computer to assist the learner. CAI uses the computer to present instruction via some terminal, either teletype or cathode ray tube (T.V. screen), while CMI uses the terminal to "manage" the instruction.

The CMI projects are based on specifying clearly "behavioral objectives" (what we want the student to accomplish), using the computer to measure a student's individual performance based on these objectives, and then prescribing from an inventory of instructional resources material related to the objectives and to the student's needs.

The procedure could be as follows:

1. Identify the instruction to be taught.
2. Give the student a test on the instruction.
3. Diagnose errors based on the test results.
4. Provide the student with reference material based on the errors made.
5. Have the student move on to the next unit when he reaches an established criterion.

SIMULATION

An important potential contribution of computers to education lies in the broad area of simulation. One area of simulation builds or examines a mathematical model of a system. The modeling notion of simulation allows one to identify and explore the influence of the various parameters of a system. A model as it is used in systems analysis, is a symbolic representation of a real life system. A model is usually expressed in the form of mathematical equations or expressions and does not resemble the real system in a physical sense. A flowchart, for example, is a model of a computer program – a graphic analog.

One might build models for the instructional aspects of education and manipulate some of the variables that effect learning. Frequency of review, rate of presentation of new material, various reward schedules and so on can be varied in order to study their relative importance in the overall learning outcome. At many business schools, computers are being used to provide games for teams of students to learn management techniques. As resources of a manufacturing operation such as capital, raw materials, people, production schedule, etc., are used as variables. The overall objective is to maximize profits by making decisions on how to develop these resources. Weeks of time are compressed by the computer, so that results of decisions are immediately available throughout the gaming session. Elementary school students are being taught basic economics by being allowed to run the economy of an ancient land. The child plays the role of king and has control over economic factors of a country. The computer, in dialogue with the child, demonstrates the effects of a decision. Thus, simulation can provide learning experiences that might otherwise not be available, for reasons of safety, equipment cost, prohibitive set-up time, or other factors of cost or convenience.

One of the main values of computers used in the simulation of environments, lies in their power to control models. This permits the artificially created situations to conform as closely as possible with reality in the following manner:

1. Accurate calculations may be quickly made from simple or complex formulas.
2. "Random" numbers may be generated and used to modify the calculation of the outcome of a particular decision.
3. Complicating circumstances may be methodically introduced in a logically consistent manner not foreign to the way in which this would happen in the real environment.
4. Situations or elements may be introduced on a "random" basis.

Brief descriptions of several games are included here to provide the reader with an indication of the direction of this aspect of computer applications in education. Credit for the development of the first three games goes to the. Board of Cooperative Educational Services, Port Chester, New York.

SUMERIAN GAME

The idea behind the Sumerian Game was first proposed by Bruce Moncreiff (IBM Corporation) in 1962 and has been extended and developed to form the current version of the Sumerian Game. The game is designed to teach sixth graders basic principles of economics as applied to the neolithic revolution in Mesopotamia during the fourth millennium B.C. After an introductory programmed tape and slide presentation to familiarize the pupil with his new role, the pupil seats himself at the computer terminal and assumes the role of Luduga I, priest-king in the city-state of Lagash in the year 3500 B.C.

His tasks are to allocate resources, apply surplus grain to the development of crafts, and – in the last part of the game – promote trade and solve increasingly more complex problems which societies encountered at that time. He is presented with a series of problematic situations and must indicate on the typewriter his decisions concerning such economic questions as how much grain to plant for the coming season, how much to save and how much to feed his people. In successive phases of the game, the pupil is faced with problems of expanding population, allocation of manpower to non-agricultural endeavors, foreign trade and other complex situations which confront a changing economy. At intervals, the "ruler" is presented with technological innovations and harassed by randomly introduced disasters. For each of his decisions the computer responds appropriately, causing the economic development of the country to proceed in a way which is dependent on the wisdom of the pupil's decisions.

SIERRA LEONE DEVELOPMENT GAME

The essential idea behind the Sierra Leone Development Game is to simulate the economic problems of a newly emerging nation, with a lesser emphasis on study of the country's culture. The pupil plays the role of an AID (Agency for International Development) officer in Sierra Leone, moving from province to province giving advice on such problems as how to increase rice and onion production, how to deal with the price structure of the diamond market, and what the best strategies are for maximizing Gross National Product.

The game has four logical divisions:

1. The student is given a computer-controlled pictorial and verbal tour through Africa and Sierra Leone. At the end of the tour, the player takes a basic examination – covering the tour's highlights – which then enables him to become a member of the AID.

2. In Sierra Leone's Northern Province, he is stationed at a cooperative farm where he allocates money for land, labor and equipment to improve crop production and promote scientific farming.

3. In the Eastern Province he distributes rice in a free market and diamonds in a controlled market.

4. Then the player moves to the capital, Freetown, to assist the Finance Ministry in balancing government expenditures among the agriculture, mining and manufacturing segments of the economy.

As the student completes his work in each province, he is given a point rating in the AID depending upon how well he finished each task.

FREE ENTERPRISE GAME

(The Toy Store and Surfboard Games)

The Free Enterprise Game consists of two phases which, although intended to be played sequentially, may be used as two distinctly separate games. In the first phase of the game the player assumes the role of the owner and operator of a small toy store. In this simulated commercial environment, the pupil makes a series of economic decisions in an attempt to increase the net worth and monthly sales of his store. The player must allocate his sales revenue among payment of expenses, remuneration for his own work, replacement of merchandise sold, and savings and/or expansion into new areas which include purchase of new equipment, additional varieties of merchandise, and taking on additional monthly expenses for promotional purposes. Unanticipated increases in monthly expenses also occur. During this phase of the game he is expected to learn by experience such general concepts and understanding of economics as the difference between goods and services, the necessity of capital investment to produce growth and the relationship between risk and return.

In the second phase of the game the player assumes the role of the owner of a firm that manufactures surfboards. If this segment of the game is played in conjunction with the first phase, the transition from sales to production is necessitated when the costs involved in further increasing the size of his retail operation are such that his money could be more profitably spent in another endeavor.

As a producer, he learns the laws of supply and demand, diminishing returns, and specialization, as well as policies of hiring, firing and settling wages. The player may produce any number of surfboards he desires (through controlling the number of workers) and ask any selling price he wants for the finished surfboards. The number of surfboards produced is simply a function of the number of machines and workers; the number sold is a function of the price asked and the overall demand at the time. The player receives a series of monthly reports informing him of his production, sales expenses and profit (or loss).

CONSUMER GAME

The purpose of the Consumer game is to teach adolescents about the problems and economics of installment buying. This is accomplished by placing students in an artificial or simulated environment which presents a number of situations requiring many of the same decisions players will eventually make in real life.

Players learn:

1. To compare the interest rates charged by different finance institutions;
2. That their credit rating (outstanding loan commitments) can affect their ability to borrow;
3. To understand fully the implications of contracts before signing, and;
4. To appreciate the mechanics of that sector of the economic system concerned with the consumer credit.

In another facet of simulation, students can develop their own models as a development of their proficiency in programming. These student developed dynamic models, can be either simple or complex depending on the grade level and ability of the students. A simple mathematical model might be an equation indicating the volume of a rectangular solid to which the student can assign different values to the variables in order to investigate the changing volume as the dimensions change.

Using simulation students can develop intuitive comprehension of the phenomena they are studying; they can explore interrelationships between variables which define the phenomena; they can detail the relative importance of parameters and the sensitivity of the simulated system to changes in these parameters; they can test hypotheses concerning the phenomena, and they can establish values of the parameters of the system.

COUNSELING

Another application of the computer in education is in the area of counseling. The counselor of today is often caught in a paradoxical situation. He spends ever more time collecting, recording and evaluating data about his students, and ever less time relating to those students as human beings. Yet, today's advanced information processing technology should enable him to shift to the computer the burden of data handling, freeing him to fulfill his unique function as a counselor.

The student *guidance counseling* system in high schools, colleges and universities provides individualized aid to each student to help him reduce his uncertainty of his educational-vocational plans. The computers' ability to accept, store, analyze and display information rapidly aids the counselor and the student. With its capacities for rapid and accurate computations, its infallible memory, its speedy retrieval and effective display, its freedom from human scruples of bias and mood and its complete objectivity, the computer can change the organization and functioning of counseling services.

A project, under the direction of Professor David V. Tiedeman, of Harvard University, is structuring an automated guidance system, in which computers help students to make decisions about schools, jobs and themselves. Aiming at a kindergarten-to-retirement-potential, the educators feed data into the model system on:

1. The students who will be using the system;

2. The job opportunities in the New England area, with emphasis on skills rather than particular jobs;

3. The predictions by economists and labor specialists of the skills that will be in highest demand in the next few years;

4. The participating schools;

5. The jobs recent Newton high school graduates have secured and their success or failures in such employment.

Most of this data will be put onto slides, tapes, and films from which the computer will select materials appropriate to the users.

It is hoped that the system will eliminate current weaknesses in the counseling system. Tiedeman points out that most students currently visit their advisors only three to four times a year and too frequently discuss small and immediate problems. The counselor lacks the time and information to deal effectively with more important issues. The computer-based system may provide critical assistance here.

A somewhat similar approach is being developed by the Systems Development Company, Santa Monica, California. SDC's computer assisted vocational counseling program was developed by Drs. Donald Estawan and John Cogswell. The computer is used by either the student or the school counselor to obtain probable predictions for success in college and vocational choices, based on the student's I.Q., grades, other test scores and courses taken previously.

As the initial step in SDC's counseling project, the procedures of a counselor in the Palo Alto School District were analyzed to derive a computer model of his performance in counseling with ninth grade students.

A program was written to accept as inputs the data from individual students' records — grades, aptitude test scores, parents' occupations, etc., analyze these data and apply the programmed decision rules developed from study of the counselor's procedures. On the basis of these rules, the computer selects and prints out certain prestored evaluative statements such as: STUDENT'S GRADES HAVE GONE DOWN; ASK ABOUT THIS IN INTERVIEW. STUDENT MAY NEED REMEDIAL COURSES; SHOULD BE WATCHED CLOSELY. LOW COUNSELING PRIORITY; NO PROBLEMS APPARENT.

An on-line interview begins with a five-minute lesson on the use of the teletype. The student's record, which is stored in the computer, is inspected, and the machine types out his grades in each course for the last semester, asking him to indicate any course with which he is having problems. He types in his own words a brief description of his difficulties, if any, and these descriptions are stored on tape for later printout and transmittal to the counselor. A student may be asked whether he plans to go to college; if so, the program assists him in selecting an appropriate type of college, university or trade school and in determining his college major. *If he does not choose college, student and computer explore other alternatives to establish his vocational interests.* He is then furnished a printout indicating his probable grades in high school and his chances of success in his chosen activity; these predictions are based on statistics accumulated by the school system. Finally, the machine assists him to select courses for the 10th, 11th, and 12th grades — evaluating his choices and advising him on required courses, appropriate course loads and the relevance of his electives to his chosen college major or vocational preference. The record of the automated interview is available to the counselor, together with evaluative comments that the computer has selected (from prestored statements) at critical junctures during the interchange. By means of these evaluative statements, the counselor is provided with a concise summary of information on the student's performance.

The School District of Philadelphia is developing a computer guidance system which allows students access to a computer for the purpose of obtaining material relating to occupational opportunities in the Philadelphia area. Students in secondary schools are using the computer to ask questions regarding occupational opportunities and to seek information leading to decisions regarding curriculum choices. This program contains information on job classifications ranging from building trade occupations to highly technical electronic trade opportunities. Students interface with the computer on teletypewriter terminals.

In addition to the above mentioned projects, the following counseling projects are in existence:

1. The IBM guidance counseling support system developed by the International Business Machines Corporation under the direction of Frank J. Minor is designed to provide students with information tailored to their individual needs. The computer stores information such as military opportunities, university and junior college curriculums, college locater information, local occupational and training opportunities, a record of the student's grades, his highest educational attainment, and his vocational interests.

2. The Rochester Automated Development Counseling System developed by the City School District of Rochester, New York, with the technical assistance of the Eastman Kodak Company, uses a multi-media package including occupational materials on microfilm, life career studies, education studies, teaching learning units, and occupational, educational and personal characteristics data bases.

3. The University of Oregon Guidepak System developed by the University of Oregon is designed for counselors to provide entry job information to students who have taken neither college preparatory nor specific vocational work in high school. Although the system is not computer based, it includes optional computer programs to store and retrieve the occupational information that the system generates.

4. The Willowbrook Computerized Vocational Information System developed for Willowbrook High School, a large comprehensive high school outside of Chicago, uses computer technology to make up-to-date vocational education available to students and counselors. The computer functions as an automated library and filing system for storing the vocational and curricula; filing student's cumulative record information.

5. The Pennsylvania State University's Computer Assisted Career Exploration System is designed for use by 9th grade boys interested in pursuing vocational and technical courses of study in high school. The system provides the boys with on-line access to occupational information stored in the computer and helps to match their attributes and occupational requirements.

6. Computer Based Course Selection and Counseling in Palo Alto Unified School District in California consists of a dialogue between the student and the computer via remote access terminals in the schools. The dialogue gives the student information about success of past 9th graders in the school on college entrance, on entry jobs, and on courses in 10th, 11th and 12th grades.

7. The Bartlesville Computer Assisted Counseling System designed for the Bartlesville Public School in Oklahoma is designed to use the computer to provide information to the counselor relevant to the following student decisions: academic course selection, vocational course selection, learning commitments, extracurricular activities, non-curricular activities, continuation of school, college selection, job selection, military obligations, and marriage.

OTHER PROJECTS

In this Guide we have referred to many school programs in describing the role of the computer in education. Naturally we cannot cover all of the computer projects currently operating throughout the United States. The following are therefore, some brief descriptions of additional projects selected as a representative sample rather than as an inclusive compendium.

At the University of California, Irvine, there is widespread use of computer assisted instruction in introductory courses and continuing development of computer facilities within several faculties. Some aspects of Science, Economics, Statistics and Social Sciences are presented by computer assisted instruction and work is underway towards extending the self-instructional elements in these subjects. Writing teams are composed of faculty members with the support of graduate and undergraduate students. The work is directed toward the use of the computer as an aid in learning.

Project PLAN, under the sponsorship of the American Institutes for Research and the Westinghouse Corporation, provides comprehensive "packages" for individual learning situations. Each package consists of a number of modules, covering five or six defined objectives for approximately two weeks' work in a given subject. Learning packages have been prepared in World History, Language Studies, Science, Social Sciences and Mathematics. Packages are chosen by the School Districts concerned, but the actual handling of the work is the responsibility of the teacher, who may include group or class discussion as well as individual and group work among the learning activities. The computer is used as an aid to the teacher in the management of the learning process. The computer also records student performance and provides regular information on individual progress for the teacher. The function of the computer is simply to perform clerical and statistical activities of a teacher support nature. These activities include test scoring, preparing records, filing, matching characteristics, and estimating probabilities. The main significance of this project is in the prominence given to structuring the curriculum, the computer role being that of managing the learning process. Of paramount importance is the clear involvement of teachers working closely with the other members of staff on the project.

Dartmouth College uses a computer system involving approximately 160 student terminals in the college, and about another 25 terminals situated singly or in pairs in 18 public schools. There are some 3,000 undergraduate and 700 graduate students at the college and computer facilities are available to all for general scientific and other uses. It is thought that the computer adds a new dimension to the education of the students. A greater depth of study than is otherwise possible is induced as, for example, in understanding derivatives, or in research into American business. The elimination of laborious repetitive calculations from the student's work in areas such as chemical engineering, has made possible a more creative approach to the course. Opportunities for simulation, for finding the optimum solution to a problem, and for giving the student a measure of control in using the computer, are of great value.

A number of projects in the area of computer assisted instruction have been undertaken at Florida State University. One such project produces programmed multi-media texts in high school science. The texts have major branching points into "excursions" allowing the more able students to gain deeper knowledge. The courses are organized to test many programmed learning and pedagogical theories. While, in principle, computer assisted instruction is available as one of the media, the main purpose is to validate the texts for non-computer assisted instructional use, using the computer to collect, store and process data. It is claimed that computer assisted instruction is about 20 percent more effective in physics teaching than normal classroom teaching, and students taking a course in computer assisted instruction maintained their performance better throughout the course.

A quite different use of CAI has been undertaken by the social work department in the FSU Graduate School of Social Work. Students from a variety of backgrounds need to be informed in subjects basic to social work. Acquaintance with concepts in Anthropology, Sociology, and Psychology is considered a necessary prerequisite for all the students. The social work department programmed into the CAI system selected topics for students to study as required. It has been ascertained that the students received a better understanding of basic concepts through this technique than they received from the classroom presentation.

The University of Texas has done some very interesting work in CAI in various areas. They have a simulated chemistry laboratory for freshman students in which a CAI terminal is used in place of laboratory experience. The student goes to the terminal just as he would go to the laboratory. He may be shown a slide or told by the typewriter that he has a test tube of colorless liquid. The computer simulates the laboratory experiment. In another program, Math pre-skill CAI courses are made available to students to teach the mathematical skills necessary to pass freshman chemistry.

The New York City Schools Project was started in March 1968. Sixteen schools have 192 terminals and it is expected that up to 6,000 students will use computer terminals for periods of 10 to 12 minutes a day. The arithmetic drill programs developed by Suppes at Stanford University are being used as the basic curricular material for this project. Research on the project has shown an increase in the student's learning ability.

A "Commonwealth Consortium," composed of the Philadelphia and Pittsburgh School Districts, the State Department of Education and the Pennsylvania State University, developed course materials in general mathematics and algebra for ninth grade pupils. The work began in March, 1968 with a team of 12 research workers including four teachers. A secondary school in Philadelphia and one in Pittsburgh each have a CAI system consisting of 30 CRTs. Approximately 60 students are assigned to the CAI program in each class. In both cases the teacher serves primarily as a manager of the classroom.

The U. S. Naval Academy is using computer assisted instruction in courses in chemistry, physics and mathematics. A desire to experiment with alternative techniques of presenting material has led to the development of a multi-media approach to teaching these subjects.

An on-line system is being used for teaching mathematics for electrical engineering students and statistics for psychology students at the University of California in Santa Barbara. Statistics of random variables is explained through watching curves develop from calculations of several values of the variables. During these sessions the students operate a terminal with a small storage tube cathode ray display and a special keyboard.

Many CAI programs have been developed at Penn State University. A course to teach medical technicians the recognition of malarial parasites in blood smears, a simulation exercise in which a simulated audiometer set is used with the "sketching" facility of the terminal to instruct students in the correct method of carrying out audio tests, and a study to provide occupational information as a basis for counseling are a few of the programs in use.

The School District of Philadelphia uses the computer to aid in the solution of many educational problems. It has sought to serve the following objectives:

(i) To use computers to facilitate and individualize instructional processes;

(ii) To develop and implement courses related to computers so that students can use these as tools, be aware of the effects they will have on their lives, and recognize their impact on society.

(iii) To develop curricula designed to acquaint students with career opportunities in data processing and to help them develop the skills necessary to enter this vocational field;

(iv) To develop, implement, and evaluate new and promising techniques of teaching such as those involved in gaming and simulation;

(v) To train teachers and other staff members of the school district in the use of computers so that they may apply them to the improvement of instruction in the school district.

Stanf University began a program of research and development in compu sisted instruction in January, 1963. In 1964, a computer based laboratory for learning and teaching was established on the Stanford University campus. An extensive program of investigation and development of computer assisted instruction for school children and university students is underway.

The Brentwood (Calif.) School project at the Ravenswood City School District began in the 1964-65 school year under the direction of Dr. Patrick Suppes, Director of the Institute for Mathematics Studies, Stanford University. In the summer of 1969, the Institute (Stanford University) was granted a contract by USOE to establish a computer-based instructional laboratory at a public school (elementary) to investigate in CAI. In the spring of 1966, the first CAI program was a program in spelling fundamentals for fourth and fifth graders. Drill and practice in spelling was provided via teletypes connected to a computer at Stanford University by telephone lines. Beginning in the fall of 1966, the Stanford-Brentwood CAI laboratory was used to teach mathematics and reading and approximately 100 first grade students from the Brentwood School. In 1970 this program involved approximately 1500 students taking lessons from various CAI programs which include drill and practice in mathematics and reading, logic and time-shared BASIC. The CAI programs provide the children with systematic daily practice commensurate with their ability and performance, and the teacher with daily and/or weekly reports of the individual child's performance. The children work for approximately 5 to 10 minutes a day on a drill and practice program and then return to their classroom. The lesson is based on the child's past performance and success with the program. In mathematics the computer program evaluates each answer of the student. If he has made an error or has taken too long to answer, he is immediately informed and the problem is repeated. If the second response is also incorrect or not answered in time, the correct answer is typed and the student sees the problem again reprinted. This gives the student the opportunity to type a correct answer to each program before proceeding to the next one. If no error is made, the student is automatically presented with the next lesson. This process continues until all problems in a given lesson have been presented to the student. At the end of a lesson, the student is given the date, his score and a personal goodbye. The computer program then signs him off – updates his records, and prepares the next drill.

A reading program is carefully structured to cover the following topics:

1. Readiness
2. Letter Identification
3. Word Identification
4. Phonics
5. Spelling Pattems
6. Word Meanings

In a project designed to teach Russian by computer assisted instruction, teletypes print out pattern drills, and the student hears simultaneous audio input over headphones from synchronized tape recorders.

At the State University of New York, Stonybrook computer assisted instruction courses in German, French and Statistics are available. The German course deals mainly with the grammatical aspects of the language and is presented almost entirely in German. The complete first year German course, as well as one hour of computer assisted instruction, includes one hour of audio linguistics in a language laboratory and three hours of conversation and reading with lectures each week.

THE FUTURE OF COMPUTERS IN EDUCATION

A basic trend in education has been evidenced over the past 20 years and can be described as a trend toward complexity. Not only has the number of s. idents been increasing but it seems that approaches to every aspect of education have increased as well. The "lock-step" of grades is no longer the major administrative system, but non-graded, continuous progress is becoming increasingly popular. Along with the idea of continuous progress comes two not so new approaches. These are individualization in instruction and flexible curriculum scheduling. The student is no longer required to confine himself to one, two or three tracks in a curriculum. The course offerings are increasing at a fantastic rate. All of this means increased complexity in administering education to students. The consequence of this complexity is the necessity of establishing new methods of instruction scheduling, reporting and grading, to say nothing of budgeting, planning and building of facilities and other aspects of educational administration.

A solution to some of the administrative and instructional aspects of education lies in the increased use of computers. Computers already have the capability for planning and administering programs of study. Computers also have the capability of scheduling, rostering, reporting and grading students as well as the capacity to retain in "data banks" information for reporting, planning, scheduling and research.

With regard to the instructional subsystem of education, individualization is becoming the preferred educational approach. Although a tutorial (individualized) approach has been considered an ideal educational method, the resources for large-scale individualized instruction have never been available. The resources, in the form of remote computer terminals, may well become increasingly available in the future. Indeed their availability may well be a requirement for adequate functioning of the educational system. Without an automated approach to education, individual teachers will not be able to monitor the educational progress made by his students.

The future of computer applications in the educational systems lies not so much in the replacement of manual processes, but in their use in new processes. Instantly available prescriptions for education and guidance is only one way of using the capabilities of the computer. The modeling (simulation) of the environment is another use that can be made with the computer. The potential is enormous, but requires the educators to "re-think" the role of the computer. The role should not be to automate but to be an integral, dynamic part of the whole system.

The use of technology in education and particularly that of the computer will continue to expand. It is hoped that this booklet, in addition to describing some of the uses of the computer in instruction presently in existence, will motivate the reader to begin thinking of the vast possibilities of the applications of the computer in this important area.

Section 6.00

GLOSSARY

Algorithm A computational procedure for solving a problem. When properly applied, an algorithm always produces a solution to the problem.

Algol An arithmetic language by which numerical procedures may be presented to a computer in standard form *algo*rithmic *l*anguage.

Alphameric A contraction that can be used equally well with alphabetic or numeric kinds of data.

Analog The representation of numerical quantities by means of physical variables; e.g., translation, rotation, voltage, or resistance.

Analog computer A scientific type computer that operates on numbers not represented by their true values but with numbers represented by measurable physical quantities such as the rotation of a shaft, the amount of voltage, the size of a displacement, and so forth.

Arithmetic unit That portion of the hardware of an automatic computer in which arithmetical and logical operations are performed.

Assemble To put together subroutines and routines into a main program.

Assembly program A computer program that takes instructions written in other machine language and converts the instructions into the language required for operation, i.e., high-speed printer.

GLOSSARY

Authors Those who design instructional material for presentation by the computer.

Base A number base — a quantity used implicitly to define some system of representing numbers by positional notation — radix.

Batch Processing Collection of data over a period of time to be sorted and processed as a group during a particular machine run.

Binary number system An internal numbering system used by computers that uses the number *two* as a base (as opposed to the numerical system that uses the number *ten*).

Bit A binary digit; a single pulse in a group of pulses; a single hole in a punched tape or punched card. Bits comprise a character; characters comprise a word.

Block diagram A graphic representation showing the logical sequence by which data is processed.

Branching A method of selecting the next operation for the computer to execute while the program is in progress, based on the computer results.

Buffer A device within a computer that serves as an electronic policeman to prevent traffic jams when a system takes in data. It holds and collects the facts and delivers them to the processing unit when needed.

Bug A mistake in the design of a routine or a computer, or a malfunction.

Byte A term to indicate a measurable portion of consecutive binary digits (bits); e.g., a 8-bit or 6-bit byte; a group of binary digits usually operated on as a unit; usually represents one alphabetic or numeric symbol.

CAI programming language A language used to "tell" a computer to display curriculum, receive and process responses, and for branching to appropriate portions of the curriculum as required by the logic of instruction.

Calculator 1. A device capable of performing arithmetic. 2. A calculator as in (1) that requires frequent manual intervention. 3. Generally and historically a device for carrying out logic and arithmetic digital operations of any kind.

Computer Assisted Instruction A method of using a computer system as a means of presenting individualized instructional material to a number of students simultaneously.

Computer Managed Instruction Uses the capability of the computer to record the progress of a student through a learning sequence, providing guidance and control are dictated by the needs of the situation.

Central processing unit The group of components of a data-processing system that contains the logical, arithmetic and control circuits for the basic system.

Cobol (Common business oriented language) A programming system that uses basic English language and then translates the English phrases into computer code programs that can be understood and executed by the computer.

Compile To prepare a machine language program from a computer program written in another programming language by making use of the overall logic structure of the program, or generating more than one machine instruction for each symbolic statement, or both, as well as performing the function of an assembler.

Criteria A standard or established level of attainment which must be reached by the student.

Criterion Referenced Testing A testing situation in which a student is evaluated on how well he achieves the established criterion.

Cybernetics The field of technology involved in the comparative study of the control and intracommunication of information handling machines in order to understand and improve communication.

Debug To search for and correct errors in a computer program.

Digital computer A computer which processes information represented by combinations of discrete or discontinuous data. As a device capable of performing sequences of internally stored arithmetic and logical operations.

Feedback Presentation of information to the student based on an analysis of his responses. This may be delayed or immediate.

Flowchart A graphical representation for the definition, analysis, or solution of a problem, in which symbols are used to represent operations, data, flow and equipment.

Fortran (formula translator) A programming system that translates statements expressed in a format similar to algebraic equations into computer language.

Garbage Unwanted and meaningless information in memory or on tape. Synonymous with Hash.

General purpose computer A computer that is designed to solve a wide class of problems.

Hardware A term used to describe the mechanical, electrical and electronic elements of a data-processing system.

Individualized Instruction Adapting instruction to individual requirements, providing for self-directed learning, self-pacing, independent study and one to one teaching.

Interface A common boundary between automatic data processing systems or parts of a single system.

Input 1. The data to be processed. 2. The state or sequence of states occuring on a specified input channel. 3. The device or collective set of devices used for bringing data into another device. 4. A channel for impressing a state on a device or logic element. 5. The process of transferring data from an external storage to an internal storage.

Input-output device A unit that accepts new data, sends it into the computer for processing, receives the results and converts them into a usable form.

Instructions A set of characters (normally consisting of a command) which, when interpreted by the control unit, causes a data-processing system to perform one of its operations.

Keypunch A keyboard actuated device that punches holes in a card to represent data.

Keypunching Transcribing alphabetical or numerical information into card by manual keyboard punching of the data.

Language A set of representations, conventions and rules used to convey information.

Latency The time from the display of an instructional stimulus to the start of the student's response.

Library A collection of organized information used for study and reference.

Light pen A device that can sense the coordinates of a point on the screen of a console utilizing the light from the cathode ray tube.

Line printer The printing of an entire line of characters as a unit.

Loop The repeated execution of a series of instructions for a fixed number of times.

Machine Language A language that is used directly by a machine. It is a set of symbols, characters or signs, and the rules for combining them, that convey instructions and information to a computer. Program steps and data are expressed in a numerical code that can be read directly and used by the computer without further translation.

Macro instruction An instruction in a source language that is equivalent to a specified sequence of machine instructions.

MICR (Magnetic Ink Character Recognition) The machine recognition of characters printed with magnetic ink.

Microsecond One-millionth of a second. A time measurement used to measure the operating speed of a computer.

Millisecond One-thousandth of a second. A time measurement used to measure the operating speed of a computer.

Model An idealized representation that demonstrates the relationship between relevant variables. Models are used to better control a real situation.

Multiplex To interleave or simultaneously transmit two or more messages on a single channel.

Nanosecond A billionth of a second. A time measurement used to measure the operating speed of a computer.

Native language A processing machine language that is peculiar to the machines of one manufacturer.

Numerical control Pertaining to the automatic control of processes by the proper interpretation of numerical data.

Off-line Pertains to operating devices not under the direct control of the central processing unit.

On-line Pertains to operating devices under the direct control of the central processing unit. An example of an on-line device is the printer that operates only under the control of the central processing unit.

Optical scanner 1. A device that scans optically and usually generates an analog or digital signal. 2. A device that optically scans printed or written data and generates their digital representations. 3. Synonymous with Visual Scanner.

Output Information transferred from internal storage to output devices to produce output cards, tapes, business forms, and so forth.

Peripheral equipment Units or device that are part of an entire data-processing system, but not actually part of a computer, i.e., an automatic typewriter functioning off-line, card sorter, reproducer, a forms burster, forms encoder, and so forth.

Printer An output device for printing out computer results as numbers, words or symbols. They can be anything from electric typewriters to high-speed printers.

Processing, Information The totality of scientific and business operations performed by a computer; the handling of data according to rules of procedure to accomplish operations such as classifying, sorting, calculating and recording.

Program A series of instructions that cause a data-processing system to process a specific application.

Programmed instruction Teaching that uses a step by step method of presenting basic elements of subject matter to a student. Programmed instruction usually alters the course of instruction depending upon the results of part instruction (branching).

Programmer A person who prepares instruction sequences without necessarily converting them into the detailed codes.

Punch card 1. A card punched with a pattern of holes to represent data. 2. A card as in (1) before being punched.

Punched tape A tape on which a pattern of holes or cuts is used to represent data.

Real-time A method of processing data so fast that there is virtually no passage of time between inquiry and result.

Remediation Instructional action taken because a learner has made an inappropriate response. Remediation decreases the likelihood of the inappropriate response.

Routine A set of instructions arranged in proper sequence to cause a computer to perform a desired task.

Run A single, continuous performance of a computer routine.

Simulate To represent the functioning of one system by another, for example, to represent one computer by another, to represent a physical system by the execution of a computer program, to represent a biological system by a mathematical model.

Simulation exercise This is an exercise that generally uses a computer as a scorekeeper while people make decisions concerning a mathematical model of the business world. The model consists of a group of cause-and-effect formulas that determine what happens when a decision is made by a human competitor.

Software 1. The collection of programs and routines associated with a computer, for example, compilers, library routines. 2. All documents associated with a computer, for example, manuals circuit diagrams. Software refers to the internal programs or routines professionally prepared to simplify programming and computer operations. These routines permit the programmer to use something close to his own language in communication with the computer. Software usually provided by manufacturers includes various assemblers, generators, subroutine libraries, compilers, operating systems, and application programs.

Source program A program written in a source language.

Storage 1. Pertaining to a device into which data can be entered, in which it can be held, and from which it can be retrieved at a later time. 2. Loosely, any device that can store data. 3. Synonymous with Memory.

System 1. An organized collection of parts united by regulated interaction. 2. An organized collection of men, machines, and methods required to accomplish a specific objective.

Systems Analyst A method, plan or pattern which includes as a minimum, the establishment of objectives presentation of instruction, evaluation, and feedback.

System, Operating An integrated collection of service routines for supervising the sequencing of programs by a computer. Synonomous with monitoring system.

Tape drive A device that moves tape past a head. Synonymous with Tape Transport.

GLOSSARY

Terminal A device by which data can leave or enter a computer system; for example, a cathode ray tube display (similar to a TV screen, or a teletypewriter).

Time sharing The use of a single processing unit to serve many users simultaneously. Each user's demands are served by the system for only a fraction of real time.

Unit record equipment Preparation materials such as keypunch machines, card readers; separated from computer itself.

Variable A quantity that can assume any of a given set of values.